

TITLE

A Method and Apparatus for Controlling the Operation of a Flexible Cross-Connect System

10 This application claims the priority of Provisional Application 60/125,526 which was filed on March 22, 1999. This application is also related to Application 09/274,078 which was also filed on March 22, 1999 (the same day as the provisional application). Applications 60/125,526 and 09/274,078 are herein incorporated by reference but are not admitted to be prior art.

Background of the Invention

Telecommunications (telecom) systems are carrying increasing amounts of information, both in long distance networks as well as in metropolitan and local area networks. At present, data traffic is growing much faster than voice traffic, and includes high bandwidth video signals. In addition to the requirement for equipment to carry increasing amounts of telecom traffic there is a need to bring this information from the long distance networks to businesses and to locations where it can be distributed to residences over access networks.

The equipment which has been developed to carry large amounts of telecom traffic includes fiber optic transport equipment which can carry high speed telecom traffic. The data rates on fiber optic systems can range from millions of bits per second (Mb/s) to billions of bits per second (Gb/s). In addition, multiple wavelengths of light can be carried on an optical fiber using Wavelength Division Multiplexing (WDM) techniques.

35 The ability to carry large amounts of telecom traffic on an optical fiber solves the long-distance point-to-point transport problem, but does not address the issue of how to add and remove traffic from the high-speed data stream. Equipment for adding

5 and removing traffic has been developed and is referred to as
"add-drop" multiplexers (ADMs).

Traditional designs for ADMs are based on the use of
multiple interface cards which receive high-speed data streams,
create a time division multiplex signal containing the multiple
10 data streams, and route the time division multiplex signal to a
cross-connect unit which can disassemble the data streams, remove
or insert particular data streams, and send the signal to another
interface card for transmission back into the networks. By
aggregating the multiple data streams into a time division
15 multiplexed data signal, the data rate of the time division
multiplexed signal is by definition several times the rate of the
maximum data rate supported by the interface cards. Traditional
ADMs have proven adequate for interface data rates in the range
of 155 Mb/s to 622 Mb/s.

However, optical signals of at least 2.4 Gb/s have become
standard, and traditional ADMs do not work for these high-speed
optical signals. That is, numerous problems arise due to the
timing associated with the multiplexing and transmission of the
high-speed signals between the interface cards and the cross-
20 connect unit. Thus, there is a need for cross-connect equipment
which can support multiple high speed data streams (i.e., at
least 2.4 Gb/s).

Standardized interfaces and transmission hierarchies for
telecom signals have been developed and include Pleisochronous
30 Digital Hierarchy (PDH), Synchronous Digital Hierarchy (SDH)
standards, and Synchronous Optical Network (SONET). In addition
to these telecom transport standards, standards have been
developed for interconnecting businesses and computers within
businesses. These Metropolitan and Local Area Network (MAN/LAN)
35 standards include Ethernet, Gigabit Ethernet, Frame Relay, and
Fiber Distributed Data Interface (FDDI). Other standards, such

5 as Integrated Services Digital Network (ISDN) and Asynchronous Transfer Mode (ATM) have been developed for use at both levels.

Individual pieces of equipment can be purchased to support telecom or MAN/LAN standards. However, these devices generally either connect data streams using a signal protocol or convert
10 entire data streams from one protocol to another. Thus, there is a need for a device which can establish interconnectivity between interfaces at the MAN/LAN level, while providing cross-connection to interfaces at the telecom network level.

Multiple interfaces are presently supported in cross-connect
15 equipment using different interface cards. High-speed interface cards must be inserted into particular slots in order to insure that the high-speed signals can be transported to and from the cross-connect unit and to and from the high-speed interface cards. It would be desirable to have a cross-connect system in
20 which all cards can support high-speed optical signals of at least 2.4 Gb/s, regardless of the card slot they are located in. Moreover, it would also be useful to have a system which would support routing, bridging, and concentration functions within MANs/LANs, as well as permitting access to telecom networks.

25 For the foregoing reasons, there is a need for a flexible cross-connect apparatus that includes a data plane and can support multiple high-speed optical interfaces in any card slot. Furthermore, the flexible cross-connect apparatus can establish connectivity between data cards and the telecom networks.

30

Summary of the Invention

The present invention discloses a method and apparatus for cross-connecting high-speed telecommunications signals at a flexible cross-connect system. A method and apparatus for
35 controlling communications between each of the cards located within the flexible cross-connect system is also disclosed. The method and apparatus also detect and report failures within the

5 system, receive and validate software upgrades from external sources, maintain synchronization within the system, and monitor communication maps for the system.

According to one embodiment, a method for controlling the operation of a flexible cross-connect system that includes a control unit, a plurality of interface cards, a cross-connect unit and a backplane is disclosed. The method includes managing provisioning data for the entire flexible cross-connect system, managing the communications between the control unit and all subordinate cards (plurality of interface cards and the cross-connect unit), and maintaining synchronization within the flexible cross-connect system.

According to one embodiment, a computer program embodied on a computer readable medium for controlling the operation of a flexible cross-connect system is disclosed. The computer program includes a code segment for providing internal interfaces between all code segments of the computer program, a code segment for managing provisioning data for the entire flexible cross-connect system, a code segment for managing the communications between the control unit and all subordinate cards, and a code segment for maintaining synchronization within the flexible cross-connect system.

According to one embodiment, a method for downloading or upgrading software for a flexible cross-connect system is disclosed. The method includes establishing communications between the flexible cross-connect system and an external management system, receiving the software download from the external management system, verifying the integrity of the software download, and storing the software download.

According to one embodiment, a computer program for downloading or upgrading software for a flexible cross-connect system is disclosed. The computer program includes a code segment for establishing communications between the flexible

5 cross-connect system and an external management system; a code segment for receiving the software download from the external management system; a code segment for verifying the integrity of the software download; and a code segment for storing the software download.

10 According to one embodiment, a method for maintaining a connection map for a flexible cross-connect system, wherein the flexible cross-connect system is a single node in at least one network and the connection map tracks a configuration for the at least one network is disclosed. The method includes storing a
15 listing of all nodes of each network that the flexible cross-connect system is a part of; detecting when a change (i.e., switching to or from a protection channel) in status for the flexible cross-connect system occurs; reporting the change to all of the nodes of each of the networks that the flexible cross-
20 connect system is a part of; and updating the connection map to indicate the change in status of the flexible cross-connect system.

According to one embodiment, a computer program for maintaining a connection map for a flexible cross-connect system is disclosed. The computer program includes a code segment for storing a listing of all nodes of each network that the flexible cross-connect system is a part of; a code segment for detecting when a change in status for the flexible cross-connect system occurs; a code segment for reporting the change to all of the
25 nodes of each of the networks that the flexible cross-connect system is a part of; and a code segment for updating the connection map to indicate the change in status of the flexible cross-connect system.

According to one embodiment, a method for monitoring and
35 maintaining the status of, and controlling the communications to, each subordinate card within a flexible cross-connect system is disclosed. The method includes monitoring an operational state

5 FIG. 3 illustrates communication channels between elements of the flexible cross-connect system, according to one embodiment;

FIG. 4 illustrates a functional diagram of the software, according to one embodiment;

10 FIG. 5 illustrates the interfaces for the processors of the system, according to one embodiment;

FIG. 6 illustrates the software supporting each of the interfaces of FIG. 5, according to one embodiment;

15 FIG. 7 illustrates the flexible cross-connect system within multiple networks, according to one embodiment; and

FIG. 8 illustrates the software architecture of the control system, according to one embodiment.

Detailed Description of the Preferred Embodiments

20 In describing a preferred embodiment of the invention illustrated in the drawings, specific terminology will be used for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical
25 equivalents which operate in a similar manner to accomplish a similar purpose.

30 With reference to the drawings, in general, and FIGS. 1 through 8 in particular, the apparatus and method of the present invention are disclosed.

The present invention supports numerous telecommunications (telecom) and networking standards, including the following which are incorporated herein by reference:

- Bellcore Standard GR-253 CORE, Synchronous Optical
35 Network (SONET) Transport Systems: Common Generic Criteria, Issue 2, December 1995;

- 5
- Bellcore Standard GR-1230 CORE, SONET Bi-directional Line-Switched Ring Equipment Generic Criteria, Issue 3A, December 1996;
 - Bellcore Standard GR-1400 CORE, SONET Uni-directional Line-Switched Ring Equipment Generic Criteria;
 - 10 • Bellcore TR-NWT-000496, SONET Add-Drop Multiplex Equipment (SONET ADM) Generic Criteria, Issue 3, May 1992;
 - Bellcore Transport System Generic Requirements FR-440, Issue No. 98, September 1998; IEEE/ANSI 802.3 Ethernet LAN specification; and
 - 15 • Networking Standards, by William Stallings, published by Addison-Wesley Publishing Company (New York, 1993).

FIG. 1 illustrates a block diagram of a flexible cross-connect system 10 capable of routing traffic across two high-bandwidth planes. The flexible cross-connect system 10 includes a telecom plane 100, such as a SONET plane, and a data plane 110. The telecom plane 100 includes telecom plane network interface subsystems 130, and the data plane 110 includes data plane network interface subsystems 140. A centralized fully non-blocking cross-connect unit (XC) 120 is located in the telecom plane 100, which interfaces with the telecom plane network interface subsystems 130 and the data plane network interface subsystems 140.

Standardized telecom traffic, such as SONET, Synchronous Digital Hierarchy (SDH) and Pleisochronous Digital Hierarchy (PDH), enters the system through the telecom plane network interface subsystems 130, such as electrical or optical interface subsystems. The telecom traffic is transmitted from the telecom plane network interface subsystems 130 over point-to-point connections 150 to the XC 120. The XC 120 processes the telecom traffic and then transmits the processed data back to a telecom network, such as a Wide Area Network (WAN), or transmits the

5 processed data to a data network, such as a Metropolitan or Local Area Network (MAN/LAN). The processed data is transmitted to the telecom network via the telecom plane network subsystem(s) 130, and to the data network via the data plane network interface subsystem(s) 140.

10 Standardized telecom signals include, but are not limited to, DS-1 (1.5 Mb/s), B-ISDN (1.5Mb/s) DS-2 (6.3Mb/s), DS-3 (44.7 Mb/s), CEPT-1 (2.048 Mb/s), CEPT-2 (8.45 Mb/s), CEPT-3 (34.37 Mb/s), CEPT-4 (139.3 Mb/s), electrical STS-1 and its multiples, electrical STM-1 and its multiples, and optical OC-1 and its
15 multiples. Other standardized and non-standardized transmission signal formats can be supported and are understood by those skilled in the art.

Standardized data traffic, such as Ethernet, enters the system through the data plane network interface subsystems 140, such as electrical or optical interface subsystems. The data plane network interface subsystems 140 communicate with the XC 120 via point-to point connections 150. The data plane 110 also allows for communications between data plane network interface subsystems 140 via point-to-point connectors 160. Thus, the data
20 traffic can be processed by multiple data plane interface subsystems 140 before being transmitted to the XC 120 or back to the data network. As with the telecom traffic, the XC 120 processes the data traffic and transmits the processed data to a telecom network or a data network.

30 Standardized data signals include, but are not limited to, packet data transport formats such as Frame Relay, Asynchronous Transfer Mode (ATM), and Integrated Services Digital Network (ISDN); and MAN/LAN formats such as Ethernet, Fiber Distributed Data Interface (FDDI), and Token Ring. The interfaces supported
35 by the data plane network interface subsystems 140 include electrical Ethernet interfaces such as 10BaseT and 100BaseT, as well as optical interfaces such as 1000BaseT and Gigabit

5 Ethernet. Other data-centric interfaces can be used and are understood by those skilled in the art.

In one embodiment, the point-to-point connections 150 between the XC 120 and the telecom plane network interface subsystems 130 or between the XC 120 and the data plane network interface subsystems 140 are all in a single specified format. For example, in a preferred embodiment, all the point-to-point connections 150 are high-speed connections realized as Synchronous Transfer Signal (STS)-192 formatted signals. The STS-192 signals are transported on a multi-trace electrical bus formed on a high-speed backplane.

In an alternative embodiment, as illustrated in FIG. 2, specific network interface subsystems are designated as high-speed interface subsystems 200 and others are designated as low-speed interface subsystems 220 having corresponding high-speed connections 230 and low-speed connections 240 to the XC 120. For example, the low-speed interconnections 240 may operate at the STS-48 rate of 2.488 Gb/s, while the high-speed interconnections 230 may operate at the STS-192 rate of 9.953 Gb/s.

The high speed network interface subsystems 200 may be realized as printed circuit boards containing active and passive electrical and optical components, and may contain multiple network interfaces 202 operating at the same or different speeds. The low speed network interface subsystems 220 may also be realized as printed circuit boards with active and passive electrical and optical components, and can contain multiple network interfaces 202 operating at the same or different speeds. As an example, a low speed network interface subsystem 220 can be realized as a DS-1 interface board supporting 14 DS-1 interfaces. Alternatively, a low speed network interface subsystem 220 can be realized as an Ethernet board supporting multiple Ethernet interfaces.

5 As illustrated in FIG. 3, the XC 120 has direct point-to-point connections 150 with each interface subsystem 301, 302, 303, 304, 309, 311, 312, 313, 314, 319. Each of the interface subsystems 301-304, 309, 311-314, and 319 represent an interface card which is either of the class of cards which are telecom
10 plane network interface subsystems 130 (high-speed) or which are data plane network interface subsystems 140 (low-speed). There are multiple point-to-point System Communication Links (SCLs) 352 between a centralized Timing, Control, and Communications subsystem (TCC) 300 and each of the interface subsystems 301-304,
15 309, 311-314, and 319. The TCC 300 is also directly connected to the XC 120 via a TCC to XC communication bus 360. In a preferred embodiment, the system has a redundant XC 325 and a redundant TCC 305.

The XC 120 provides the switching fabric for the system. As
20 the central switching element for the system, the XC 120 features low latency and fast switching to establish connections and perform time division switching at an STS-1 level between the XC 120 and the telecom network interface subsystem 130 and between the XC 120 and the data plane network interface subsystem 140.

25 The TCC 300 performs system initialization, provisioning, alarm reporting, maintenance, diagnostics, Internet Protocol (IP) address detection/resolution, SONET Data Communications Channel (DCC) termination, and system fault detection for the system. The TCC 300 also ensures that the system maintains Bellcore
30 timing requirements. These functions can be performed by a processor which executes a set of computer instructions stored on a computer readable memory.

FIG. 4 illustrates a functional diagram of the software 400
35 of the flexible cross-connect system 10. The software 400 can be divided into two functional subsystems, a Network Management Interface System (NMIS) 410 and a Control System (CS) 420. The NMIS 410 provides the interface between and communicates with

5 external machines, such as a PC or workstation. The external machine may either be an Element Management System (EMS) 430 or an off-node Network Management System (NMS) 440. A Java and C++ based Corba system is preferably utilized to provide a computing environment between the NMIS 410 and the EMS 430 or the NMS 440. 10 The NMIS 410 also performs validation of all commands received from the EMS 430 or the NMS 440, and transmits the validated inputs to the CS 420. The NMIS 410 receives all information related to the status of the flexible cross-connect system 10 from the CS 420. In a preferred embodiment, the NMIS 410 can 15 transmit the data to a Java application in a browser, the NMS 440 for presentation to a user, or to the OMS. In one embodiment, the NMIS 410 is written using an object oriented software language, and preferably is written using C++. In a preferred embodiment, the NMIS 410 is also written in Java, to the extent 20 that the NMIS 410 can transmit Java commands to the EMS 430 or the NMS 440.

095341-032500
000000
In a preferred embodiment, the EMS 430 and the NMS 440 will act as a Java Virtual Machine (JVM). That is, each of the devices communicating with the flexible cross-connect system 10 will be able to receive the Java commands transmitted from the NMIS 410 as if it were a Java processor. Stated alternatively, 25 the EMS 430 and the NMS 440 act a web browser and receive Java commands from the NMIS 410 which is acting as a web server.

30 In one embodiment, as illustrated in Fig. 5, the software 400 is hosted on two separate processors, with one processor being the master processor and the other processor being a slave. The master processor will handle communications with the EMS 430 or the NMS 440, and control the overall operation of the flexible cross-connect system 10. The master processor will thus be known 35 as the Control Processor (CP) 500. In a preferred embodiment, the CP 500 is an MPC860 processor or the like. The slave processor will handle Data Communications Channels (DCCs) to

5 other flexible cross-connect systems 10 and be used for the additional ports. The slave processor will thus be known as the DCC processor (DCCP) 550. In a preferred embodiment, the DCCP 550 is an MPC860MH processor or the like.

Fig. 5 illustrates the interfaces of each of the processors 10 (the CP 500 and the DCCP 550) running the software 400. In one embodiment, the CP 500 has two Serial Management Controllers (SMCs) 502, 504 and four Serial Communications Controllers (SCCs) 506, 508, 510, 512, and the DCCP 550 has one SMC 552 and four SCCs 554, 556, 558, 560.

Each processor, the CP 500 and the DCCP 550, will host remote monitoring software which tracks the status of the system so as to aid in the debugging process. Access to the status/debug information is made available external to the flexible cross-connect system 10 by using SMCs 502 and 552, operating as a Universal Asynchronous Receiver/Transmitter (UART), to provide the status/debug information over a port. In a preferred embodiment, the ports are 19.2 Kb/s serial RJ11 ports.

The CP 500 is capable of communicating with the EMS 430 or the NMS 440 over a LAN. The CP 500 interfaces with the LAN via an interface supported by the SCC 506. In a preferred embodiment, the interface is a 10 Mb/s Ethernet (IEEE 802.3) interface.

Each processor is capable of communicating with the other processor via an inter-processor link. The SCCs 510 and 558 support ports which provide the inter-processor link between the CP 500 and the DCCP 550. The link allows the processors to communicate provisioning, status and alarms between themselves. In a preferred embodiment, the link is a serial communications link and the ports support communications at 1-2 Mb/s.

The DCCP 550 is provided with an interface, supported by the SCC 560, for modem dial out in the event the LAN interface is

002230 "F2H560
003341 0335
004452 0446
005563 0550
006674 0664
007785 0778
008896 0892
009907 0906
010018 0101
011129 0115
012240 0129
013351 0141
014462 0151
015573 0166
016684 0177
017795 0188
018806 0199
019917 0210
021028 0223
022139 0236
023250 0249
024361 0260
025472 0279
026583 0298
027694 0317
028805 0336
029916 0355
031027 0374
032138 0393
033249 0412
034360 0431
035471 0450
036582 0469
037693 0488
038804 0507
039915 0526
041026 0545
042137 0564
043248 0583
044359 0602
045470 0621
046581 0640
047692 0659
048803 0678
049914 0697
051025 0716
052136 0735
053247 0754
054358 0773
055469 0792
056580 0811
057691 0830
058802 0849
059913 0868
061024 0887
062135 0906
063246 0925
064357 0944
065468 0963
066579 0982
067690 1001
068801 1020
069912 1039
071023 1058
072134 1077
073245 1096
074356 1115
075467 1134
076578 1153
077689 1172
078800 1191
079911 1210
081022 1229
082133 1248
083244 1267
084355 1286
085466 1305
086577 1324
087688 1343
088800 1362
089911 1381
091022 1400
092133 1419
093244 1438
094355 1457
095466 1476
096577 1495
097688 1514
098800 1533
099911 1552
101022 1571
102133 1590
103244 1609
104355 1628
105466 1647
106577 1666
107688 1685
108800 1704
109911 1723
111022 1742
112133 1761
113244 1780
114355 1799
115466 1818
116577 1837
117688 1856
118800 1875
119911 1894
121022 1913
122133 1932
123244 1951
124355 1970
125466 1989
126577 2008
127688 2027
128800 2046
129911 2065
131022 2084
132133 2103
133244 2122
134355 2141
135466 2160
136577 2179
137688 2198
138800 2217
139911 2236
141022 2255
142133 2274
143244 2293
144355 2312
145466 2331
146577 2350
147688 2369
148800 2388
149911 2407
151022 2426
152133 2445
153244 2464
154355 2483
155466 2502
156577 2521
157688 2540
158800 2559
159911 2578
161022 2597
162133 2616
163244 2635
164355 2654
165466 2673
166577 2692
167688 2711
168800 2730
169911 2749
171022 2768
172133 2787
173244 2806
174355 2825
175466 2844
176577 2863
177688 2882
178800 2901
179911 2920
181022 2939
182133 2958
183244 2977
184355 2996
185466 3015
186577 3034
187688 3053
188800 3072
189911 3091
191022 3110
192133 3129
193244 3148
194355 3167
195466 3186
196577 3205
197688 3224
198800 3243
199911 3262
201022 3281
202133 3300
203244 3319
204355 3338
205466 3357
206577 3376
207688 3395
208800 3414
209911 3433
211022 3452
212133 3471
213244 3490
214355 3509
215466 3528
216577 3547
217688 3566
218800 3585
219911 3604
221022 3623
222133 3642
223244 3661
224355 3680
225466 3699
226577 3718
227688 3737
228800 3756
229911 3775
231022 3794
232133 3813
233244 3832
234355 3851
235466 3870
236577 3889
237688 3908
238800 3927
239911 3946
241022 3965
242133 3984
243244 4003
244355 4022
245466 4041
246577 4060
247688 4079
248800 4098
249911 4117
251022 4136
252133 4155
253244 4174
254355 4193
255466 4212
256577 4231
257688 4250
258800 4269
259911 4288
261022 4307
262133 4326
263244 4345
264355 4364
265466 4383
266577 4402
267688 4421
268800 4440
269911 4459
271022 4478
272133 4497
273244 4516
274355 4535
275466 4554
276577 4573
277688 4592
278800 4611
279911 4630
281022 4649
282133 4668
283244 4687
284355 4706
285466 4725
286577 4744
287688 4763
288800 4782
289911 4801
291022 4820
292133 4839
293244 4858
294355 4877
295466 4896
296577 4915
297688 4934
298800 4953
299911 4972
301022 4991
302133 5010
303244 5029
304355 5048
305466 5067
306577 5086
307688 5105
308800 5124
309911 5143
311022 5162
312133 5181
313244 5200
314355 5219
315466 5238
316577 5257
317688 5276
318800 5295
319911 5314
321022 5333
322133 5352
323244 5371
324355 5390
325466 5409
326577 5428
327688 5447
328800 5466
329911 5485
331022 5504
332133 5523
333244 5542
334355 5561
335466 5580
336577 5599
337688 5618
338800 5637
339911 5656
341022 5675
342133 5694
343244 5713
344355 5732
345466 5751
346577 5770
347688 5789
348800 5808
349911 5827
351022 5846
352133 5865
353244 5884
354355 5903
355466 5922
356577 5941
357688 5960
358800 5979
359911 5998
361022 6017
362133 6036
363244 6055
364355 6074
365466 6093
366577 6112
367688 6131
368800 6150
369911 6169
371022 6188
372133 6207
373244 6226
374355 6245
375466 6264
376577 6283
377688 6302
378800 6321
379911 6340
381022 6359
382133 6378
383244 6397
384355 6416
385466 6435
386577 6454
387688 6473
388800 6492
389911 6511
391022 6530
392133 6549
393244 6568
394355 6587
395466 6606
396577 6625
397688 6644
398800 6663
399911 6682
401022 6701
402133 6720
403244 6739
404355 6758
405466 6777
406577 6796
407688 6815
408800 6834
409911 6853
411022 6872
412133 6891
413244 6910
414355 6929
415466 6948
416577 6967
417688 6986
418800 7005
419911 7024
421022 7043
422133 7062
423244 7081
424355 7100
425466 7119
426577 7138
427688 7157
428800 7176
429911 7195
431022 7214
432133 7233
433244 7252
434355 7271
435466 7290
436577 7309
437688 7328
438800 7347
439911 7366
441022 7385
442133 7404
443244 7423
444355 7442
445466 7461
446577 7480
447688 7499
448800 7518
449911 7537
451022 7556
452133 7575
453244 7594
454355 7613
455466 7632
456577 7651
457688 7670
458800 7689
459911 7708
461022 7727
462133 7746
463244 7765
464355 7784
465466 7803
466577 7822
467688 7841
468800 7860
469911 7879
471022 7898
472133 7917
473244 7936
474355 7955
475466 7974
476577 7993
477688 8012
478800 8031
479911 8050
481022 8069
482133 8088
483244 8107
484355 8126
485466 8145
486577 8164
487688 8183
488800 8202
489911 8221
491022 8240
492133 8259
493244 8278
494355 8297
495466 8316
496577 8335
497688 8354
498800 8373
499911 8392
501022 8411
502133 8430
503244 8449
504355 8468
505466 8487
506577 8506
507688 8525
508800 8544
509911 8563
511022 8582
512133 8601
513244 8620
514355 8639
515466 8658
516577 8677
517688 8696
518800 8715
519911 8734
521022 8753
522133 8772
523244 8791
524355 8810
525466 8829
526577 8848
527688 8867
528800 8886
529911 8905
531022 8924
532133 8943
533244 8962
534355 8981
535466 9000
536577 9019
537688 9038
538800 9057
539911 9076
541022 9095
542133 9114
543244 9133
544355 9152
545466 9171
546577 9190
547688 9209
548800 9228
549911 9247
551022 9266
552133 9285
553244 9304
554355 9323
555466 9342
556577 9361
557688 9380
558800 9399
559911 9418
561022 9437
562133 9456
563244 9475
564355 9494
565466 9513
566577 9532
567688 9551
568800 9570
569911 9589
571022 9608
572133 9627
573244 9646
574355 9665
575466 9684
576577 9703
577688 9722
578800 9741
579911 9760
581022 9779
582133 9798
583244 9817
584355 9836
585466 9855
586577 9874
587688 9893
588800 9912
589911 9931
591022 9950
592133 9969
593244 9988
594355 10007
595466 10026
596577 10045
597688 10064
598800 10083
599911 10102
601022 10121
602133 10140
603244 10159
604355 10178
605466 10197
606577 10216
607688 10235
608800 10254
609911 10273
611022 10292
612133 10311
613244 10330
614355 10349
615466 10368
616577 10387
617688 10406
618800 10425
619911 10444
621022 10463
622133 10482
623244 10501
624355 10520
625466 10539
626577 10558
627688 10577
628800 10596
629911 10615
631022 10634
632133 10653
633244 10672
634355 10691
635466 10710
636577 10729
637688 10748
638800 10767
639911 10786
641022 10805
642133 10824
643244 10843
644355 10862
645466 10881
646577 10900
647688 10919
648800 10938
649911 10957
651022 10976
652133 10995
653244 11014
654355 11033
655466 11052
656577 11071
657688 11090
658800 11109
659911 11128
661022 11147
662133 11166
663244 11185
664355 11204
665466 11223
666577 11242
667688 11261
668800 11280
669911 11299
671022 11318
672133 11337
673244 11356
674355 11375
675466 11394
676577 11413
677688 11432
678800 11451
679911 11470
681022 11489
682133 11508
683244 11527
684355 11546
685466 11565
686577 11584
687688 11603
688800 11622
689911 11641
691022 11660
692133 11679
693244 11698
694355 11717
695466 11736
696577 11755
697688 11774
698800 11793
699911 11812
701022 11831
702133 11850
703244 11869
704355 11888
705466 11907
706577 11926
707688 11945
708800 11964
709911 11983
711022 12002
712133 12021
713244 12040
714355 12059
715466 12078
716577 12097
717688 12116
718800 12135
719911 12154
721022 12173
722133 12192
723244 12211
724355 12230
725466 12249
726577 12268
727688 12287
728800 12306
729911 12325
731022 12344
732133 12363
733244 12382
734355 12401
735466 12420
736577 12439
737688 12458
738800 12477
739911 12496
741022 12515
742133 12534
743244 12553
744355 12572
745466 12591
746577 12610
747688 12629
748800 12648
749911 12667
751022 12686
752133 12705
753244 12724
754355 12743
755466 12762
756577 12781
757688 12800
758800 12819
759911 12838
761022 12857
762133 12876
763244 12895
764355 12914
765466 12933
766577 12952
767688 12971
768800 12990
769911 13009
771022 13028
772133 13047
773244 13066
774355 13085
775466 13104
776577 13123
777688 13142
778800 13161
779911 13180
781022 13199
782133 13218
783244 13237
784355 13256
785466 13275
786577 13294
787688 13313
788800 13332
789911 13351
791022 13370
792133 13389
793244 13408
794355 13427
795466 13446
796577 13465
797688 13484
798800 13503
799911 13522
801022 13541
802133 13560
803244 13579
804355 13598
805466 13617
806577 13636
807688 13655
808800 13674
809911 13693
811022 13712
812133 13731
813244 13750
814355 13769
815466 13788
816577 13807
817688 13826
818800 13845
819911 13864
821022 13883
822133 13902
823244 13921
824355 13940
825466 13959
826577 13978
827688 13997
828800 14016
829911 14035
831022 14054
832133 14073
833244 14092
834355 14111
835466 14130
836577 14149
837688 14168
838800 14187
839911 14206
841022 14225
842133 14244
843244 14263
844355 14282
845466 14301
846577 14320
847688 14339
848800 14358
849911 14377
851022 14396
852133 14415
853244 14434
854355 14453
855466 14472
856577 14491
857688 14510
858800 14529
859911 14548
861022 14567
862133 14586
863244 14605
864355 14624
865466 14643
866577 14662
867688 14681
868800 14700
869911 14719
871022 14738
872133 14757
873244 14776
874355 14795
875466 14814
876577 14833
877688 14852
878800 14871
879911 14890
881022 14909
882133 14928
883244 14947
884355 14966
885466 14985
886577 15004
887688 15023
888800 15042
889911 15061
891022 15080
892133 15099
893244 15118
894355 15137
895466 15156
896577 15175
897688 15194
898800 15213
899911 15232
901022 15251
902133 15270
903244 15289
904355 15308
905466 15327
906577 15346
907688 15365
908800 15384
909911 15403
911022 15422
912133 15441
913244 15460
914355 15479
915466 15498
916577 15517
917688 15536
918800 15555
919911 15574
921022 15593
922133 15612
923244 15631
924355 15650
925466 15669
926577 15688
927688 15707
928800 15726
929911 15745
931022 15764
932133 15783
933244 15802
934355 15821
935466 15840
936577 15859
937688 15878
938800 15897
939911 15916
941022 15935
942133 15954
943244 15973
944355 15992
945466 16011
946577 16030
947688 16049
948800 16068
949911 16087
951022 16106
952133 16125
953244 16144
954355 16163
955466 16182
956577 16201
957688 16220
958800 16239
959911 16258
961022 16277
962133 16296
963244 16315
964355 16334
965466 16353
966577 16372
967688 16391
968800 16410
969911 16429
971022 16448
972133 16467
973244 16486
974355 16505
975466 16524
976577 16543
977688 16562
978800 16581
979911 16600
981022 16619
982133 16638
983244 16657
984355 16676
985466 16695
986577 16714
987688 16733
988800 16752
989911 16771
991022 16790
992133 16809
993244 16828
994355 16847
995466 16866
996577 16885
997688 16904
998800 16923
999911 16942
1001022 16961
1002133 16980
1003244 17000
1004355 17019
1005466 17038
1006577 17057
1007688 17076
1008800 17095
1009911 17114
1011022 17133
1012133 17152
1013244 17171
1014355 17190
1015466 17209
1016577 17228
1017688 17247
1018800 17266
1019911 17285
1021022 17304
10221

5 control software module 608, and an inter-card messaging module
610 communicate with each other utilizing the TCP/IP stack 600.
The craft driver 604 supports the SMC driver 504 for the craft
interface port, the remote monitoring module 606 supports the SMC
driver 502 for the debug port, and the inter-card messaging
10 module 610 supports the SCC driver 510 for the inter-card
communications port and the SCC driver 512 for the SCL port.

The DCCP 550 includes a TCP/IP Stack 650 on top of a router
652 for communicating between the software modules on the DCCP
550, subtending shelves feeding the main shelf via the packet
15 shelf LAN interface (SCC driver 554), and other flexible cross-
connect systems 10 via the DCC port (SCC driver 556). As
illustrated, a modem driver 654, a remote monitoring module 656,
a control software module 658, and an inter-card messaging module
660 communicate with each other utilizing the TCP/IP stack 650.
20 The modem driver 654 supports the SCC driver 560 for the modem
interface port, the remote monitoring module 656 supports the SMC
driver 552 for the debug port, and the inter-card messaging
module 660 supports the SCC driver 558 for the inter-card
interface port.

002200 "F2H5560
25 The interconnections described in Figs 5 and 6 allow the
flexible cross-connect system 10 to be connected to multiple
networks at one time. In a preferred embodiment, the flexible
cross-connect system 10 allows for up to 10 DCC connections, 2
LAN connections and 1 modem connection. Thus, the flexible
30 cross-connect system 10 could be part of 13 sub-networks at one
time. In a preferred embodiment, a routing protocol, such as RIP
or Open Shortest Path First (OSPF), is utilized which allows the
connections to be unnumbered so that a single IP address can be
used to identify the flexible cross-connect system 10 for each of
35 the networks that it is connected to. The single IP address
would be the address for the management LAN.

5 Fig. 7 illustrates a sample view of the flexible cross-
connect system 10 within multiple networks. In this figure, a
flexible cross-connect system 10 (identified as NE1) is part of a
network ring consisting of NE1-NE4. Thus, two, of the ten DCC
connections are used to have NE1 be part of this network ring.
10 The NE1 is also connected to a rack LAN via the packet shelf LAN
interface port (SCC 554), a management LAN via the management LAN
interface port (SCC 506), and a modem via the modem port (SCC
560). Each of the PPP connections will not have a unique IP
address, instead the single IP address for each sub-network the
15 NE1 is part of is the IP address for the NE1 to management LAN
connection.

FIG. 8 illustrates the software architecture, according to
one embodiment. The software may be written in an object
oriented language such as JAVA, C or C++. In a preferred
embodiment, the software is written using C and C++ programming
languages, which are running together on one operating system,
such as VxWorks® real time operating system sold by Wind River
Systems Corporation. In a preferred embodiment, the low-level
software which communicates between boards in the system (the CS
420) is written in C, while the interface software which
communicates with the EMS 430 or the NMS 440 (the NMIS 410) is
written in C++ and Java. In a preferred embodiment, the software
runs on the CP 500 and the DCCP 550.

The software architecture includes a Network Management
30 Interface module (NMI) 800, a Provisioning Manager module (PM)
810, an Equipment and Link State Manager module (ELSM) 820, and
Inter-Card Communications module (ICC) 830, a Database Manager
module (DM) 840, an Alarm Filtering and Reporting module (AFR)
850, a Bi-directional Line Switched Rings (BLSR) Connection Map
35 Manager module (BCMM) 860, a Synchronization Manager module (SM)
870, an Embedded De-bugger module (ED) 875, a SW Program Manager

5 module (SPM) 880, an Inter-Node Communications module (INC) 890,
and a Switching Agent module (SA) 895.

The NMI 800 serves as the interface to the EMS 430 and the
NMS 440. In a preferred embodiment, the NMI 800 is realized in
the C++ programming language, and allows the use of any browser
10 in a network element running a TCP/IP stack to address the system
10.

The PM 810 is responsible for managing a provisioning
database for the entire flexible cross-connect system 10. The PM
810 interfaces with subordinate cards via the ELSM 820 and to the
15 management software via the NMI 800. The PM 810 interfaces with
a persistent database 842 via the DM 840. The PM 810 retrieves
data, including equipment and service data, from the persistent
database 842 after a TCC 300 restart and transmits the data to
the MS and the subordinate cards. The PM 810 receives
20 provisioning updates from the MS, stores the updates in RAM and
the persistent database 842, and notifies the affected cards of
the provisioning updates. When a subordinate card requests
provisioning data, the PM 810 retrieves the relevant provisioning
information from the database 842 and transmits it to the
25 requesting card. In an embodiment that includes a redundant TCC
300, the PM 810 periodically updates the database 842 on the
redundant TCC 300. The PM 810 provides an interface to the MS
for backing up and restoring the database to an external system.

The ELSM 820 is the central point of communications between
30 the TCC 300 and all other subordinate cards. The ELSM 820
monitors and maintains information about the state of each slot,
card, and communications link in the system 10. It notifies
other components of the TCC when a subordinate card needs
service. It blocks information from being sent to a subordinate
35 card if the subordinate card is in the wrong state. For example,
the ELSM 820 would prevent a provisioning update message from
being sent to a subordinate card that is in the process of

5 updating its SW. The ELSM 820 communicates with the interface
cards via the ICC 830. In a preferred embodiment, the ELSM 820
acts as the single authority on the state of each component in
the system. The ELSM 820 on each non facility protected card is
responsible for initiating an equipment protection switch when a
10 partial or full failure is detected on a card. In a preferred
embodiment, a card presence/alive message is transmitted over an
SCL 352 from a non facility protected card to peer cards,
subordinate cards, the TCC, and the XC 120. The ELSM 820 is
responsible for monitoring this link and initiating the proper
15 action when a failure is detected.

The ICC 830 is responsible for communicating with the
subordinate cards. It receives signals from each of the
subordinate cards and determines which of the other subordinate
cards the signal is being transmitted to based on a routing byte
within the cell. It maintains a priority queue, and preferably a
high priority queue and a low priority queue, for each
subordinate card. It detects and discards corrupt signals
received from the subordinate cards.

002200-12421-03225
20
The AFR 850 performs alarm filtering for the TCC 300 and the
system 10. That is, when the arrival or removal of a failure
condition is detected, the AFR 850 confirms that the condition
has persisted for the requisite period of time, and filters out
those that do not persist for the requisite time. The PM 810 is
responsible for determining the appropriate filter times and
30 providing them to the AFR 850. Once the arrival or removal of
the failure condition clears the appropriate filter, the AFR 850
reports the change in alarm condition to the management system
(EMS 430 or NMS 440). The interface cards and the XC 120 also
perform failure filtering so that errors are not reported to the
35 TCC 300 until the failure (or removal of the failure) has existed
for a predetermined amount of time.

5 The BCMM 860 maintains information related to ring
configurations for each node in the entire network. Each node
needs to know its identification within the network ring so that
it can determine when switch requests are directed to it and when
they should be passed along to another node. When a ring
10 configuration is modified, switched to or from a protection
channel, at one node of the entire network, the BCMM 860 notifies
all of the other nodes of the entire network. In a preferred
embodiment, the BCMM utilizes the K1/K2 bytes of the SONET line
overhead to transmit this data as well as TCP/IP messages over
15 the DCC.

The SM 870 supports several timing-related services
including configuring and monitoring an internal stratum 3 clock
reference, provisioning and monitoring of a Building Integrated
Timing Supply (BITS) input, provisioning and control of the DSX-1
20 formatted BITS output, and selection of the timing reference for
the system. In addition, the SM 870 selects the timing reference
for the BITS output, processes and acts upon synchronization
status messages, and controls synchronization switching on
synchronization reference changes.

25 The ED 875 provides the ability to analyze software
behavior.

The SPM 880 manages software tracking, downloading and
upgrading. That is, the SPM 880 keeps track of the SW versions
that are utilized by each of the cards within the system 10, and
30 ensures the SW versions are either upgraded or replaced by new
versions when appropriate. For example, when the flexible cross-
connect system 10 receives a software upgrade, the SPM 880
establishes communications with the NMI 800 so that a SW load can
be received. The SPM 880 then validates the integrity of the SW
35 load and stores the load in a non-volatile file system. The SPM
880 then ensures that the subordinate cards have access to the
new software when they boot. Moreover, the SPM 880 can update

5 the boot code and drivers for the system 10 and each subordinate card when necessary. The SPM 880 stores the SW, whether it be the original or a downloaded version, in a SW database 882.

The INC 890 supports communications between the system and other nodes, using both TCP/IP and OSPF protocols.

10 The SA 895 controls the switching of cards (interface, XC 120, 125, or TCC 300, 305) or connections (PPPs 150, SCLs 352, or communication bus 360) within the system 10 from redundant to active when there is a failure in the active one. Thus, the system can autonomously recover from failures.

15 The present system can be utilized in a variety of configurations supporting transport of data on MAN/LAN, interLATA and interexchange networks. Because the system can establish cross connections between any interface cards and can use a data plane for local switching, a wide variety of transport
20 configurations can be supported, including configurations in which a virtual LAN is created in the data plane 110, and access to the telecom plane 100 is granted for transport to other nodes.

25 Although this invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made, which clearly fall within the scope of the invention. The invention is intended to be protected broadly within the spirit and scope of the appended claims.